Project Title: Regional Socio-Economic Viability Assessment of Shellfish Aquaculture

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Introduction

In response to Governor Kaine's initiative to safeguard shellfish habitat areas and the sustainability of Virginia's shellfish aquaculture industry, the Virginia Coastal Zone Management (CZM) Program and Virginia Department of Environmental Quality (DEQ) combined efforts to promote shellfish aquaculture across Virginia's coastal waters and the Eastern Shore. In September 2007, a Notice of Intended Regulatory Action (NOIRA) was proposed to consider the establishment of "aquaculture enhancement areas" on the Eastern Shore of Virginia. This rulemaking did not intend to revise the existing Shellfish Buffer Zone Public Hearing section (9 VAC 25-260-270), but rather it focused on providing additional protection to high quality water. Besides requiring point source dischargers to conduct an analysis of alternative options to discharging effluent into designated "aquaculture enhancement areas", but the Water Board would be given the ability to disapprove a permit proposal if, through the analysis, it was found that there was an alternative discharging option that had less of an environmental impact.

Although the Commonwealth has taken initiative to promote shellfish aquaculture, a need was recognized for a regional evaluation of the usefulness and implications of promoting shellfish aquaculture across three Planning District Commissions (PDCs), including Accomack-Northampton, the Middle Peninsula and the Northern Neck. This project considered to aspects of promoting shellfish aquaculture within the selected PDC regions.

First, a social informant analysis was conducted through key informant interviews in order to captured stakeholder's knowledge base and perceptions of aquaculture, population growth, land/water use conflicts, regulations, and waterfront access. While specific issues often vary across the three PDCs, there is a need for a social understanding of shellfish aquaculture.

A critical aspect of ensuring the growth and survival of Virginia's shellfish aquaculture industry, in the face of increasing coastal population growth, is to maintain stringent water quality conditions, and thus, a review of alternative wastewater treatment options. This part of the project will include a cost-effectiveness analysis of alternative wastewater treatment technologies. The need to evaluate the economic costs of alternative uses for wastewater treatment is not only desired by DEQ, but local town planners and PDC staff may find this assessment beneficial.

Product 1: Socio-economic regional assessment of select PDC's in relation to expansion of shellfish aquaculture as an industry

According to the Virginia Marine Resource Commission (VMRC), shellfish aquaculture is the propagation, rearing, enhancement and harvesting of hatchery produced molluscan organisms in controlled or selected environments, which are conducted on the tidal waters of the Commonwealth. Aquaculture within the Commonwealth of Virginia ranks eighth in the United States based on the value of total aquaculture products sold (USDA, 2003). It is valued at approximately $40.9 million (USDA, 2003). Furthermore in 2003, shellfish aquaculture production in Virginia accounted for approximately 77.3% of all aquaculture saltwater organism sales (NASS and VDACS, 2003). Respectfully, of the 77.3%, clams (mature) accounted for 76.5% of those sales (NASS and VDACS, 2003). Though the clam farms in the Commonwealth lead the nation in the culture of hard clams, both the clam and oyster aquaculture industry continue to grow.

Decisions regarding the shellfish aquaculture industry in the Commonwealth are a collaborative effort between a variety of stakeholders, including agriculturalists, local government, the aquaculture industry, community groups, and realtors/developers. According to Grimble and Wellard (1997) as well as Petts and Leach (2000), stakeholders are individuals or groups (organized or unorganized) who have an interest in a particular issue or system. Their interest may be financial, moral, legal, personal, community based, direct or indirect. Stakeholders may affect (determine) decisions or actions, while others are affected by decisions or actions (positive or negative) (Mazur et al., 2004). Finally, it is important to note that stakeholders have varying degrees of influence in the decision making process as well as varying degrees of participation (ie. active or passive) (Mazur et al., 2004).

2. Approach

Social perception assessments of aquaculture are few and far between. However, sociologists studying aquaculture believe that social science can make an important contribution to understanding the prospects of aquaculture development since many problems related to this innovation are social and institutional, rather than technical in nature (Bailey, Jentoft, and Sinclair, 1996). Within countries where the aquaculture industry has shown economic sustainability in the global market, including Australia, China, Canada, and some Mediterranean countries, social perceptions have been captured through the implementation of public surveys and key informant interviews. As a result of a thorough literature review a study from the Australian Government, Bureau of Rural Science in regards to capturing community perceptions of aquaculture (Mazur, Aslin and Byron, 2005) was used as a model for the construction of the interview guide used in this project.

Key informant interviews were conducted to collect qualitative data in regards to shellfish aquaculture. Key informants covered a range of stakeholder groups including local government, community groups, the aquaculture industry, the agricultural industry and realtors/developers. In general, key informants are particularly knowledgeable and can articulate ideas about an issue, and may also provide useful information about what is happening in subgroups within a community (Patton, 1980). Through a stratified sampling method key informants were chosen based on particular elements or characteristics of the homogenous population (Babbie, 1973). In this project geography and occupation (ie. stakeholder group) were the selection elements. The researcher selected key informants from the population based on their availability and/or accessibility. Through a convenience sampling technique, 9 key informants were chosen. The researcher intended to have a total of 10 key informants for the project, two key informants from each stakeholder group, however due to the unavailability of realtors/developers as well as a lack of interest, in some cases, in participating in this project, only one key informant was interviewed for this stakeholder group.

The target population was three PDC regions:

Planning District Commission	**Counties**
Northern Neck	Lancaster, Northumberland, Richmond and Westmoreland
Middle Peninsula	Essex, Middlesex, Mathews, King and Queen, King William and Gloucester
Accomack-Northampton (Eastern Shore)	Northampton and Accomack

Each PDC region falls in “Tidewater Virginia”. According to the Chesapeake Bay Preservation Act “Tidewater Virginia” is a jurisdictional boundary that defines Virginia’s Coastal Zone.

Interviews were conducted face-to-face, and over the phone, on a date and at a time compromised between the key informant and the interviewer. The overall objective was to gather specific information and insight about shellfish aquaculture from key informants. With this said, in some interviews the interview guide, which consisted on eleven questions, was followed in sequential order, while there were other interviews where questions were answered in no particular order. Not only was the sequence of the interview was dependent by the answers provided by the interviewee, but the researcher used her discretion to order to create a logical and congruent flow to the interview. Ultimately the questions provided direction for the answers and questions were adjusted to gain the desired information (Marshall, 2005). Moreover the questions were open ended to provide the key informant direction in his/her answer, but the freedom to express their perceptions, opinions, and knowledge of shellfish aquaculture. Standardized open-ended format, as applied in this study, reduced some inherent biases which results from interviewing.

Once interviews were conducted, they were transcribed and analyzed. Through a content analysis, major themes were identified and denoted. Themes encompassed phrases, words, and concepts that were associated with each other. For instance husbandry was identified as a theme. While the word husbandry was only specifically mentioned by one respondent, the theme of husbandry encompassed “raising”, “taking care of”, “cultivation” and “production” since the definitions of these words all intertwined.

3. Findings

This diverse group of stakeholders, including aquaculturists, agriculturists, realtors/developers, local government, and community groups, provided information that spanned the entire knowledge spectrum of shellfish aquaculture. This section will profile a summary of findings for each question. Within the tables provided below, common themes and words have been highlighted to showcase repetition amongst the stakeholder groups. It is important to note that in the majority of cases, when respondents were asked one question their response answered other questions within the interview guide. The following section references the question that was asked, however the responses may not have been a direct response to the question, but information that was provided throughout the entire interview.

3.1. Aquaculture

When respondents were asked to explain aquaculture, in general, or to define aquaculture, there were two major concepts that were mentioned by interviewees, including “husbandry” and “harvesting” the organism (Table 1). Although respondents did not consistently know the particular types of organisms involved in aquaculture, when asked about aquaculture, at least one respondent from each stakeholder group specifically spoke of shellfish aquaculture. One respondent from the community group and a respondent from the aquaculture group referred to aquaculture as agriculture in an aquatic environment. Furthermore, there were respondents that described aquaculture with opinions and speculation. For example, “I think that it’s wonderful” and “it’s the future of the oyster industry in the Chesapeake Bay.”

Table 1: Stakeholders knowledge and perception of aquaculture

Stakeholder Group	Responses
Agriculturist	• Production of clams and oyster in floats in the water..they buy the young…and raise them and they sell them • Raise catfish in ponds…salmon is raised
Aquaculturist	• Farming of shellfish • Growing, spawning the stock and raising the seed until big enough to plant on the bottom and then taking care of them and harvesting them when they’re ready • Intensive land based systems, ponds, for both shellfish and fish
Community Groups	• Husbandry of marine or freshwater animals in marine or freshwater setting. It is purchasing seed or larval fish, or what have you and cultivating it in an artificial environmental or river or tributary in nets or cages. • The aquatic counter part of agriculture • Production- either culture or harvest of wild shellfish, fish or marine animals for commercial consumption
Local Government	• Mari-based aquaculture is the growing of shellfish in water • Aquaculture is more the growing of either finfish or shellfish on land • Its wonderful
Realtors/Developers	• It’s the future of the oyster industry in the Chesapeake Bay
Common Themes: ***husbandry*** ***harvest***	

3.2. Sustainable aquaculture

When respondents were asked how they would describe sustainable aquaculture there were three common themes amongst stakeholder groups (Table 2). First, respondents stated that sustainable aquaculture was a practice that would have low or minimal effects on the environment. Second, respondents mentioned the duration of a sustainable product or industry, something that keeps “going on and on and on”, “consistently propagating”, and ultimately a “continuous process”. The third theme that respondents mentioned was economic in nature. Stakeholders from the community group and from local government described shellfish aquaculture as “something good for the economy” and “if you can make a living doing it, then it’s sustainable.” However there were some interviewees, from the agriculture group and realtor/developer group that just commented on the current state of the aquaculture industry and did not necessarily provide a clear understanding of sustainable aquaculture.

Table 2: Stakeholders knowledge and perception of aquaculture

Stakeholder Group	Responses
Agriculturist	• Low impact…would not impact the environment as much as the environment probably impacts them [shellfish] • It's good
Aquaculturist	• Keep it going on and on and on • Consistently propagate a product or an animal with minimal environmental impact • What are you producing, how much negative impact are you having, how much positive impact are you having, how does that balance out
Community Groups	• Continuing basis producing a quality good product for human consumption with minimal environmental impacts • Something that is good for the environment and something that is good for the economy • Continue in the long term without degrading the resource, while simultaneously being productive and commercially viable
Local Government	• governmental framework, whether or not the part of the economy is functioning correctly, and whether or not you want that [shellfish aquaculture] as part of your economy • private sector considers it from a profit and loss perceptive, whether or not you can make a living doing it. If you can make a living doing it, then it's sustainable • Water quality is the bottom line for sustainable aquaculture
Realtors/Developers	• Hard to get a sustainable with predators in the bay
Common Themes:	***Environmental*** ***Duration*** ***Economy***

3.3. An alternative: shellfish aquaculture vs harvesting wild shellfish populations

Respondents were asked whether they believed that shellfish aquaculture is an alternative to harvesting wild shellfish populations. With the exception of one participant shellfish aquaculture was considered an alternative to harvesting wild shellfish populations amongst all stakeholder groups. In some cases the respondent matter-of-factly answered the question with one word, "Sure", "Yes", or "Absolutely." On the contrary one respondent did not believe that a comparison could be made between shellfish aquaculture and the harvesting of wild shellfish:

> “When you harvest wild populations all you do is take….I took hard clams, and when you harvest the wild populations all you do is take and you never put anything back. With aquaculture you’re really only taking what you’re putting in the wild…”

3.4. Shellfish aquaculture

When asked to describe or define shellfish aquaculture there were two major themes common in responses, husbandry and the technical aspect of shellfish aquaculture (Table 3). All stakeholder groups, except for the realtor/developer group mentioned a word that could be associated with husbandry. The second theme that was consistent throughout all stakeholder groups, to some degree, was the mention of the technical aspect of the shellfish aquaculture.

Table 3: Stakeholder knowledge and perceptions of shellfish aquaculture

Stakeholder Group	Responses
Agriculturist	• *Was defined when asked what aquaculture was:* Production of clams and oyster in floats in the water..they buy the young…and raise them and they sell them • Cages in shallow water and stake them off to hold their position
Aquaculturist	• *Was defined when asked what aquaculture was:* Growing, spawning the stock and raising the seed until big enough to plant on the bottom and then taking care of them and harvesting them when they're ready • *Described the entire technical process of shellfish aquaculture (see quote below)*
Community Groups	• Shellfish means bivalves, like clams, oysters, scallops, mussels. In the Chesapeake Bay it is clams and oyster, nobody is grow mussels • Buy oyster seed from hatchery, put it in grow out bags or cages, put the bags on racks and put cages on leased bottom from state • Husbandry of shellfish until they are ready for market • Planting [shellfish] under controlled circumstances and growing them to maturity for harvest and commercial setting
Local Government	• Growing the spat and re-growing that either off bottom in elevated cages or float cages and then finfish aquaculture operations as well • Private TOGA, Tidewater Oysters Growers Association, and these are the waterfront property owners that recreationally grow oysters and clams. • Commercial base, where there's off bottom aquaculture where oysters or clams are grown in cages, or you might have the growing of oysters or clams or fish inshore in a closed system • Don't know much technically. How much technical is there other than water quality • Get seed clams, place them to raise them til they are a certain size and then they transplant them til they are mature
Realtors/Developers	• There's intensive (ie. Cages) and spat on shell • Spat on shell is where you put them overboard unprotected
Common Themes: ***husbandry*** ***technique***	

Respondents who were involved in the aquaculture industry provided a thorough summary of the technical process of shellfish aquaculture and the particular practices that are used to produce a marketable product:

> "[Shellfish aquaculture] starts with the propagation of mono cultures of micro algae which is grown in a facility with a combination of UV treatment and filtration, a small amount of, a very minuscule amount of fertilizer which is absorbed in the process of propagating the algae and when sufficient cultures and , in gallons per day, are obtained which takes….about 6 weeks…..simply feed genetically chosen brood stock of *virginica* oysters or *mercenaria* hard clams…for 6 to 8 weeks and then through a temperature manipulation spawn the brood stock and produce swimming fertilized eggs and swimming larvae and a post set juvenile animal which is maybe 250 microns in size and at this point these animals are taken out of still culture, aerated still culture, and put in recirculating systems for a short period of time, maybe 2 weeks to a month. And eventually you put [them] in an open flow through system grown for 4 to 6 weeks until they are placed out in the field in a variety of different procedures to obtain size large enough that eventually you winter a clam over after its about 10 months old and at that point you begin…..field propagation or grow out that takes an additional couple of years until clams are eventually sold to market, or……seed is sold in various sizes and stages through the propagation process to other field growers."

3.5. Species involved in shellfish aquaculture

When asked what species may be involved in shellfish aquaculture, there were a variety of answers (Table 4). The majority of interviewees knew that in Virginia, oysters and clams were involved in shellfish aquaculture. Some respondents provided common names of the hard clam that referenced the size of the hard clam (ie. little neck, cherrystone, middle neck, and top neck), while there were other respondents that could identify the hard clam (*Mercenaria mercenaria*) and the Virginia's native eastern oyster (*Crassostra virginica*) by their genius and specie names.

Table 4: Types of "species" that are involved in shellfish aquaculture in Virginia

Stakeholder Group	Responses
Agriculturist	• Oysters • Chinese or Japanese oyster • Clams
Aquaculturist	• *mercenaria* hard clam • *virginica* • hard shell clam • little necks, middle neck and top necks
Community Groups	• Virginia's native eastern oyster, *Crassostra virginica* • Hard clam, *Mercenaria mercenaria* • Little neck • Cherrystone
Local Government	• Native Virginia Oysters • Native Virginia clams • Clam • Oyster • Asian oyster
Realtors/Developers	• Asian oyster • Virginia oyster

3.6. Factors or stresses that might contribute to the mortality or the poor growth of these organisms

There were a variety of key concepts that were mentioned by respondents, however "water quality" and environmental factors were the overwhelming answers. One respondent from the local government group stated, "the temperature of the water is one thing, the dying off of the vegetation" was a specific contributing factor. Moreover a respondent from the community group mentioned that due to poor water quality they "have lost 65% of our oyster crop here in this creek due to persistent algae blooms" and that "low DO levels may make oysters more susceptible to two protozoan parasites [Dermo and MSX]." Runoff from agriculture and urban areas, sedimentation, overboard discharge (point source discharges) and storms were also mentioned as contributing environmental factors that affected the morality or poor growth of shellfish. Other concepts were economic, including the initial capital costs, and the demand of the product, and social, including the stealing of products, use conflict, and the manual labor involved.

3.7. Differences between shellfish aquaculture and other forms of aquaculture (ie. finfish)

When respondents were asked to state the differences between shellfish aquaculture practices and other forms of aquaculture (ie. Finfish) common themes were mentioned (Table 5). In particular the way in which finfish tend to be held and raised in stationary pens was mentioned. Another common theme entailed comparisons between the feeding techniques of finfish and shellfish aquaculture. While shellfish feed naturally, finfish were feed artificial feed. Moreover there were some respondents that concluded that there were negative environmental impacts tied to finfish practices. Although some were unable to specifically identify negative impacts, a respondent from the community group established a connection between finfish practices and environmental impacts:

> "[in finfish aquaculture there is a] net pen or fish pen and it's in a stationary area and there is persistent feeding or continued feeding over the grow out phase, a lot of that food can fall to the bottom. It can lead to algae blooms, eutrophication or excessive nutrient or fouled water along with the fish waste products."

However there were some respondents that admitted they were unable to answer this question.

Table 5: Perceptions and knowledge of differences between shellfish aquaculture and finfish aquaculture

Stakeholder Group	Responses
Agriculturist	• Confined production operation • Finfish can escape • Unable to answer question
Aquaculturist	• [finfish] are in pens and feed artificially (ie. Palette or processed food) • Finfish aquaculture have waste problems
Community Groups	• Artificial feed for finfish…feeding is consistent over the grow out phase and the food can fall to the bottom and lead to algae blooms or excessive nutrients • Shellfish are filtering organism. They remove nutrients from water • Stationary area • Natural feed for shellfish • Negative effects….Concentrated waste
Local Government	• Design architecture…adapting the technology to fit the particular geographic conditions • More pollution with finfish aquaculture
Realtors/Developers	• Feed and harvest fish • Can't answer that question well
Common Themes: ***Environmental impacts*** ***Feed*** ***Holding technique***	

3.8. Challenges of shellfish aquaculture

When respondents were asked to state the challenges of shellfish aquaculture, responses were very diverse (Table 6). However there were themes that were repeated amongst stakeholder groups, including runoff and the effects of runoff on water quality, disease and predators, use conflict and misinformation. Not only did one respondent from the agriculturists group mention that there is “competition with the waterways,” but one respondent from the community group, stated that use conflicts on the land that are affecting the water ways:

> “[working waterfronts], are disappearing so quickly because the infrastructure or the seafood industry is declining and so is the infrastructure disappears the that property gets gobbled up by developers and people who want to put up condos and so we are losing our water front access.”

This same community group respondent continued by saying that residents “are fearful that the Bay will be overtaken by steal cages and steal racks….Oyster farming, is something new and there’s a lot of misinformation and misunderstanding…” One theme that was consistent in all stakeholder responses was how water quality was impacted by runoff. A respondent from the local government group stated that, “unless you address agriculture you’re not going to solve this problem [water quality]. When you spread manure on these fields and there are no regulations about the runoff into the water. Then you’ll never solve the problem.” Later the respondent continued and said, “the big thing you’re going to have to do is address this runoff from farmland. We have thousands and thousands of acres of impervious surface from tomatoes farming because we allow plasticulture.” Although not a common theme among stakeholder groups, a respondent from the local government group stated that “our coastal localities have to decide if they want this type of industry within their land use policy framework. If they do, then, I think, they need to change their land use planning tools to allow for the expansion of aquaculture.”

Table 6: Perceptions of challenges of shellfish aquaculture

Stakeholder Group	Responses
Agriculturist	• "Finger blithe" – people stealing the product from grounds • Storms • Runoff • High element of risk and success is dependent on environment • use conflicts
Aquaculturist	• Predators (ie. Crabs, bullfish, cownose ray) • "Bringing agriculture to the table and have the agriculture people understand that the sheet flows and the sedimentation flows are going off the agriculture areas into the waterways" • Unreasonable farm practices
Community Groups	• Persistent algae blooms • Disease – Dermo and MSX • Disease in juvenile clams • Use conflict • Misinformation – "[Fear] that the Bay will be overtaken by steal cages and steal rakes • Misinformation and misunderstanding amongst all user groups • Working waterfront is disappearing. • Water access is being lost due to privatization of property. • Labor intensive • Is the demand there?
Local Government	• Land use policy framework • Public policy • Agriculture runoff and urban runoff • "Government doesn't tell the people the truth" • Wild populations have been over worked • Disease: MSX and Dermo • Clean water • There are lots of variables, development, discharge of sewage, treated effluent, change of the shoreline, etc • The market will make a difference in how aquaculture is promoted • Management of wastewater discharge • Discharge from chicken houses into water
Realtors/Developers	• Money – "watermen do not have the resources to go out there start a hatchery and be putting stuff on the bottom" • Predators (ie. Cow nose ray) • Disease (ie. MSX and Dermo) • Water quality
Common Themes: ***disease/predators*** ***runoff and water quality*** ***misinformation*** ***use conflicts***	

3.9. Coexisting with other regional industries

When respondents were asked whether they believed that the shellfish aquaculture industry is coexisting well with other industries within the region the overwhelming answer was yes (Table 6). However some respondents did mention agriculture practices and the effects that runoff from the agriculture fields has on water quality needed for shellfish aquaculture practices. According to an agriculturist, “There have been some issues with the plastic mulch production here on the shore, primarily steak tomatoes; there have been issues downstream from there. I have also talked to people, [name of aquaculturist], and they impound water, they told me this, they impound water so they know how to deal with runoff conditions. They just know that issue exists they don’t really know exactly where, what the problem is, but they know that in a rain event they need to use impounded water.”

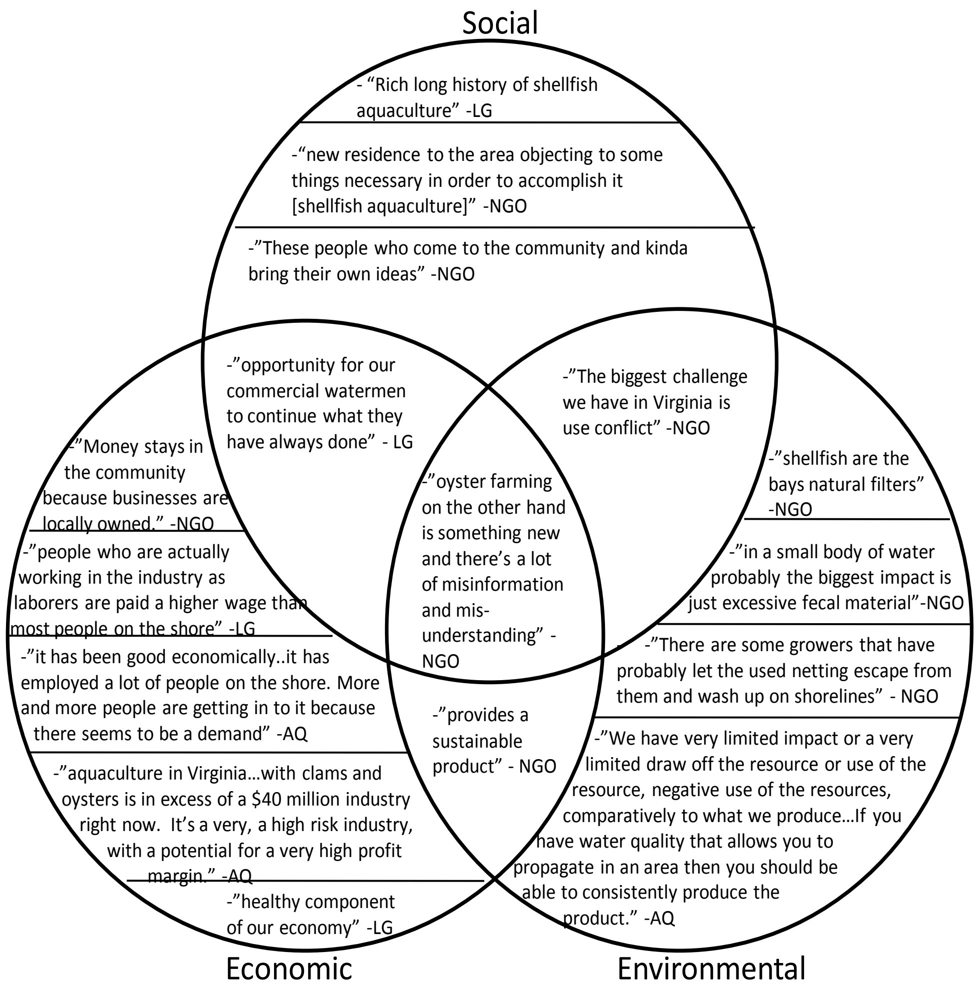
Table 7: Perceptions of shellfish aquaculture coexisting with other industries in the region

Stakeholder Group	Responses
Agriculturist	• It is. There have been some issues with the plastic mulch production, primarily steak tomatoes…there have been issues down stream • Don’t know why it wouldn’t
Aquaculturist	• Yeah • Coexisting pretty well as long as nobody communicates, has to address, or pay for anything that would create a water quality standard improvement
Community Groups	• Absolutely
Local Government	• Absolutely • If you clean up the runoff from farm land • Improving water quality would not just benefit aquaculture, but tourism and our whole way of life
Realtors/Developers	• Yes, there’s no negative effect • Watermen need to start to get into it

3.10. Social, economic or environmental impacts of shellfish aquaculture

When asked what were the social, economic, or environmental impacts of shellfish aquaculture, several of the respondents were quick to respond with economic impacts, including job opportunities and revenues. Moreover when respondents considered the environmental “impacts”, they focused primarily on the negative impacts and in some cases the interviewer needed to specifically ask if they believed that shellfish aquaculture had any positive impacts on the environment. Figure 1 depicts the key social, economic and environmental impacts of shellfish aquaculture that were mentioned by the respondents.

Figure 1: Social, economic and environmental impacts of shellfish aquaculture.



3.11. Regional advantages gained from shellfish aquaculture

When asked what advantages the region may gain from shellfish aquaculture answers were primarily economic and social in nature. However two respondents did recognize that shellfish aquaculture could improve water quality within the region. Economic factors that could be gained from aquaculture included employment, locally and regionally, production of a sustainable product, a viable seafood industry, diversity of revenue, and ultimately revenue. Socially the Chesapeake Bay region could be nationally recognized for their oyster and culturally, this new industry would provide watermen an option to continue their livelihood on the water.

3.12. Fitting into regional dynamics

When respondents were asked to provide some insight into how shellfish aquaculture might fit into their regional dynamics, as population and industrial and residential development increases, respondents took a variety of approaches (Table 8) to answer this question. However there was one common theme throughout stakeholder groups, with the exception of the local government group, which were issues associated with water quality. Two respondents, one from the local government group and one from the aquaculturist group, shared a common belief that industrial development was not a concern. Another theme that was mentioned by the community and local government group was the concept of planning, managing and changing local policy. According to the local government respondent, "It's a question of public policy. If your local governments want this sector of their economy to grow they're going to need to change their public policy to allow it to grow. If not, it will exist as its own just like commercial crabbing does, just like commercial gill netting does where it's a market segment. But aquaculture is such a specialized operation that if it's to exist and expand local government needs to develop policy to do that."

Table 8: Perceptions of shellfish aquaculture fitting into regional dynamics

Stakeholder Group	Responses
Agriculturist	• The industry is coexisting, but plastic mulch production has been created issues downstream….however aquaculturists deal with runoff conditions (ie. they impound water) • Do not know much about this • "I don't know why it wouldn't"
Aquaculturist	• It's a good business in the area • They are doing some stuff in their zoning • Not worried about industrial growth • Though there's room for development, water quality may be degraded. It's a matter of priority and what people are willing to pay for • It comes to the quality of the sheet flow that's entering the estuary
Community Groups	• If growth and development are properly planned and managed the two can coexist • County needs to recognized the importance and value of this developing industry…if not growth of development will impact water quality needed for safe and healthy oysters • there is support from counties • There a good chance to allow aquaculture a long term part of the economy
Local Government	• Depends on whether local governments want this sector in their economy. If they do they need to change public policy • Industrial development will not affect aquaculture
Realtors/Developers	• Oysters are politically popular…a lot of residents "have little cages at the end often their dock and they're growing" oysters and they "all think that they are cleaning the Chesapeake Bay" • Misunderstanding and misperception of what over fishing is • If improvements [in water quality] were made there could be benefits for all
Common Themes: water quality planning and management	

3.13. Managed and/or regulated in the future

When stakeholders were asked how they believed shellfish aquaculture should be managed and/or regulated in the future, common themes included local government and county participation as well as the state (Table 9). There were some participants that went as far as to specifically mention improving water quality, through heightened water quality standards and management of runoff from agricultural lands. There was one respondent from local government that suggested to speak to members of the industry to understand the needs, but did not know new enough to comment specifically. Moreover another respondent mentioned that the Chesapeake Bay should be managed under one ecosystem management plan, rather than following a single specie management plan.

Table 9: Perceptions of how shellfish aquaculture should be managed and/or regulated in the future

Stakeholder Group	Responses
Agriculturist	• *Implied that there was a lot of paper work involved and was empathic to their situation* • Counties should be supportive
Aquaculturist	• VMRC (Virginia Marine Resource Commission) • Current regulation is not overwhelming but is substantial • “Don’t know if anyone possibly going to figure out anyway…. to regulate us to much more.” • Preserve water quality statewide….Do something locality to improve current minimum standard for water quality • Address agriculture minimum standards
Community Groups	• Regulated and managed by the state • If each locality regulated tan industry “it’s just going to be so screwed up” • Needs regulation to stabilize the conditions in which it works
Local Government	• VMRC to manage natural resources including clams, fish and products that are harvested • Local government to manage use, industry the actual harvest of resources, the transporting of the resource and the regulating and the permitting of the infrastructure • Local governments need to develop policy to expand aquaculture • “I would like to hear what the industry itself has to say…I’m not sure what regulations would be applicable to them in the future.” • Clean up runoff from farms • Not opposed to regulation but there should be justification
Realtors/Developers	• Manage an ecosystem and stop single species type management….deal with the pollution problems • Provide a replenishment fee to oystermen • Involve the watermen to get the industry back
Common Themes: state government local government water quality	

3.14. Improving dialogue about shellfish aquaculture

When respondents were asked to provide some suggestion to improve dialogue about shellfish aquaculture amongst state and local government, the industry and the community there were two common themes that prevailed, including education and dialogue. Respondents from the aquaculture and local government groups believed that bringing “everyone to the table” will improve dialogue about shellfish aquaculture. Also according to a respondent from the community group the aquaculture industry needs to continue to "minimize their PR problems. They may also want to take a stronger, positive role too, in disseminating information about the economic consequences and various other things."

Table 9: Suggestions to improve dialogue about shellfish aquaculture

Stakeholder Group	Responses
Agriculturist	• Advertising, but may be expensive and can't measure effectiveness • Provide more information about aquaculture to the community
Aquaculturist	• Don't know. Not involved in that end of it. • Bring everyone to the table • Projects to improve water quality is going to create opinion and dialogue and there's probably no going to be a lot of agreement.
Community Groups	• Education: brochures and literature • Virginia Seafood Council can promote dialogue • Create a Virginia Shellfish Growers Association to promote education • Minimize PR problems • Take a stronger positive role to provide information about economic consequences, etc. • Advertise • Engage the new section of the community • Have local government understand the situation
Local Government	• Get a better understanding of what the seafood industry needs • "put them around the table and talk about it" • Allow public to communicate their thoughts to government without fear
Realtors/Developers	• There is already dialogue…the oyster is politically popular
Common Themes: ***dialogue*** ***education***	

4. Conclusions:

In summary there were several themes that were repeatedly mentioned amongst stakeholder groups, including husbandry, harvest, the economy, techniques of aquaculture and social aspects. However environmental concerns, and more specifically water quality concerns, were the overwhelming theme. Negative impacts to water quality as a result of agriculture runoff were mentioned by each stakeholder group, at least once throughout the interview process. Respondents from the agricultural group recognized that "agriculture is an easy target from runoff issues," however mentioned that there was "a study done by George Simmons at Virginia Tech and he developed a system to determine if the *E.coli* in the aquatic system was sourced from wild life or humans and he was able to determine that the predominate source of *E. coli* in the water was raccoons and deer." Respondents from the realtor/developer, aquaculturist, and the local group stressed the importance of water quality needed for shellfish and believed runoff from agriculture fields needed to be managed. According to a respondent from the community group, factors or stresses that contribute to the morality or poor growth of shellfish was not specifically due to poor water quality as a result of agriculture runoff, but it is a result of "excessive nitrogen and phosphorus entering the water from runoff, from agriculture, from air deposition, from storm water, from sewage treatment plants, failing septic systems that promote algae blooms."

The second theme that each stakeholder group mentioned was economic benefits of shellfish aquaculture. To some degree each stakeholder articulated the importance of shellfish aquaculture within their regional dynamics. Although respondents were not able to answer all questioned asked in the interview they did understand that shellfish aquaculture was a good thing, that it could not be done without high water quality, and that the future of the seafood industry and/or the livelihoods of watermen would depend on shellfish aquaculture.

5. Discussion:

Due to the small sample size, the qualitative data provided within this document should not be used to generalize the thoughts, opinions, and knowledge of shellfish aquaculture amongst all members of the selected stakeholder groups. However the collected information does provide a snap shot of concerns from individuals within stakeholder groups, which may potentially be shared by others.

Further research to capture social perceptions of shellfish aquaculture is recommended. With the Commonwealth showing an interest in promoting shellfish aquaculture, it is necessary to understand regional public perceptions and knowledge of shellfish aquaculture. According to Bardach (1997) social forces may significantly hinder any sustainable aquaculture plan to reach its full potential, even under ideal biological and economic conditions – yet it is often overlooked in most designs. This suggests that an understanding of social perceptions of the shellfish aquaculture industry within the Commonwealth of Virginia may provide assistance to local coastal resource planners to prioritize and manage shellfish aquaculture and the issues that are associated with this industry. Moreover these perceptions may also provide direction for future management and discussion points for localities.

Product 2: An economic and technological assessment of alternative wastewater treatments

The need to evaluate the economic costs of alternative uses for wastewater treatment is not only desired by DEQ, but local town planners and PDC staff may find this assessment beneficial. This assessment may satisfy the knowledge gap associated with meeting water quality criteria for maintaining the shellfish aquaculture industry while still accommodating coastal population growth. This quantitative analysis reviews alternative wastewater technology options, a cost assessment of the options, and how to conduct an alternatives assessment.

6. Regulations

There are several state and federal regulations involved in the protection of water quality within the Commonwealth of Virginia.

Clean Water Act of 1972, is federal legislation, enabled by the United States Environmental Protection Agency (USEPA), to protect surface water quality in the United States. The statute focuses on reducing direct pollutant discharges into waterways, financing municipal wastewater treatment facilities, and managing polluted runoff, with the objective of restoring and maintaining the chemical, physical, and biological integrity the water (USEPA, 2008). This legislation also authorizes the issuing of the National Pollutant Discharge Elimination System permit.

Specifically in Virginia, there are two types of wastewater permits issued in regards to discharging wastewater containing any material harmful to health or the environment to surface water or onto the land where it might enter or cause contamination to surface or groundwater (DEQ, 2008). The Virginia Pollutant Discharge Elimination System (VPDES) permit is required for discharges into surface water. It establishes specific water quality standards to be meet by the discharger in order to provide maximum protection to surface water quality. The other permit that the Commonwealth may issue is the Virginia Pollution Abatement (VPA) permit. Facilities with this permit are able to discharge treated wastewater onto land in a manner that does not result in a discharge into a stream or into the groundwater (DEQ, 2008).

To further regulate water quality in Virginia, the State Water Control Law (VAC 25-260) mandates the protection of the state's waters through water quality standards, criteria, and an antidegradation policy. Water quality standards designate all state waters for one the following uses: recreational activities (ie. swimming and boating), the propagation and growth of indigenous populations of aquatic life and wildlife, or the production of edible and marketable natural resources (ie. fish and shellfish) (9 VAC 25-260-10). The criteria for water quality standards explain that all state waters are to be free from substances that interfere with designated uses (9 VAC25-260-20). However, due to the difficulty of regulating interferences with designated uses, the criteria establish numerical standards to simplify enforcement. And finally the antidegradation policy states that all waters within the Commonwealth shall be assigned a tier of antidegradation protection (9 VAC 25-260-30) (Table 1). This policy is applied whenever a proposed activity has the potential to affect existing surface water quality.

Table 1: Antidegradation policy tier classification

Tier	Description
Tier 1	Specifies that existing instream water uses and the level of water quality to protect the existing uses shall be maintained and protected. This means that as a minimum, all waters should meet adopted water quality standards.
Tier 2	Protects water that is better than specified water quality standards. Only in limited circumstances may water quality be lowered in these waters.
Tier 3	Are exceptional waters where no new, additional or increased discharge of sewage , industrial wastes or other pollution are allowed. These waters must be specifically listed in the regulation.

Currently, DEQ sets regulations that only pertain to point source discharges, however according to the USEPA's National Quality Inventory 2000 report, non point sources in many areas contribute to the majority of the total nutrient loading into water ways (USEPA, 2002). Sources may include runoff from agricultural and urban areas, as well as leaking wastewater treatment systems (ie. onsite systems and centralized systems). Nonpoint sources are voluntarily managed through best management practices (BMPs) as well as indirectly managed by the Virginia Department Health (VDH) as they regulate onsite sewage water systems.

The Division of Onsite Sewage of Water Services provides human health protection and groundwater quality through the implementation of regulations governing private wells, and onsite wastewater treatment and disposal systems (VDH, 2008). VDH supervises the construction, location, and operation of alternative discharging sewage treatment systems with flows less than or equal to 1,000 gallons per day on a yearly average (12 VAC 5-640-10). Recently the VDH, who are the regulatory authority over onsite systems, has recognized the need to implement inspection and maintenance requirements of onsite systems. Affective July 1, 2009, the Board of Health, in conjunction with the Board of Waterworks and Wastewater Works Operators and Onsite Sewage System Professionals, will adopt regulations for the licensure of (i) onsite soil evaluators; (ii) installers of alternative onsite sewage systems and (iii) operators of alternative onsite sewage systems. This regulation will require licensed individuals to meet appropriate educational and training standards, have relevant work experience, demonstrate knowledge and skill, commit to application fees to cover the costs of the program, renewal fees, and meet schedules and other criteria set by the Board (State Water Control Board, 2007). This regulation intends to reduce leaking and outdated onsite systems and ultimately decrease contamination from onsite systems into adjacent ground and surface water sources.

7. Technology Summary

Treatment systems may be classified as decentralized or centralized systems. Decentralized systems consist of onsite or clustered systems. According to the US Census Bureau decentralized systems serve 25% of US households and are implemented in almost 33% of new development, however more than half these systems are thirty years old (USEPA, 2005). The remaining 75% of households in the US are served through centralized (public) wastewater collection and treatment systems (USEPA, 2004).

With advances in wastewater treatment technologies there has been an increased awareness in wastewater treatment management. Currently onsite wastewater management focuses primarily on adequate treatment of wastewater and dispersal of treated wastewater at or near the place of generation (Jantrania and Gross, 2006). The conventional systems, consisting of a septic tank and drainage field, have seen upgrades with the addition of alternative secondary and/or tertiary treatment systems. These alternative systems/units treat the wastewater within the septic tank. Then the water will be recirculated back into the septic tank for dilution purposes, or the water will be pumped into a tertiary treatment system (ie. drainage field, chemical disinfection, photochemical disinfection). Moreover, centralized wastewater treatment systems have also considered alternative secondary and tertiary wastewater treatment options, to not only become more cost-effective, but to meet new effluent standards set by the Commonwealth. For instance, effective in 2006, the

Commonwealth mandated that the majority of wastewater treatment facilities reduce nitrogen and phosphorus loads in discharged effluent.

Alternative technologies have the ability to be integrated into decentralized systems as well as centralized systems; however the quality and quantity of the wastewater, the receiving environment and the cost of the system will ultimately influence the type of treatment system that is utilized. Additionally, county ordinances with the intention to manage onsite systems, to assist as a land use management tool, may also be an influencing factor.

7.1. Septic Tank

Conventional onsite wastewater treatment technologies have typically included a septic tank and drainage field. As depicted in Figure 1 (Appendix A), wastewater from the residence enters the septic tank and is eventually dispersed through a drainage field.

The septic tank is a pretreatment unit where separation between the solids and wastewater occurs (Appendix A: Figure 2). While solids settle to the bottom of the tank, fats and scum accumulate at the top to create a distinct stratification within the unit. Between the top and bottom layers, aerobic and/or anaerobic biologic digestion of the waste will occur. However, digestion of the waste requires the sewage to remain within the tank for approximately 36-72 hours (Anderson and Gustafson, 2004). Treatment of wastewater within a septic tank is expected to be less than 45%, while more than 55% of treatment is expected from a subsurface drain field (Jantrania and Gross, 2006). Although the operation of a septic tank is simple, which reduces the cost of the septic tank, the system does need regular cleaning every 24 to 36 months (Anderson and Gustafson, 2004).

According to the National Association of Wastewater Transporters, septic tank capacities for residences are commonly a minimum of 1,000 gallons, or 400 gallons per bedroom, and for other establishments the capacity is five times the average design flow of the system (Anderson and Gustafson, 2004).

7.2. Aerobic Treatment Unit (ATU)

Aerobic Treatment Units are secondary treatment systems that introduce oxygen to the septic tank through aeration (Appendix A: Figure 3). The addition of oxygen promotes the growth of aerobic bacteria that assist in the digestion of organic wastes. Aerobic microbes convert the organic compounds into energy, new cells, as well as residual matter (Jantrania and Gross, 2006). Consequently, this increases the removal of biochemical oxygen demand (BOD) from the water (Anderson and Gustafson, 2004). When water passes through the ATU, it enters the clarifier where further separation of the solids and effluent will occur. The solids will settle back into the aeration chamber where they will continue to be biologically digested, while the effluent will flow into the dispersal system. Ultimately the ATU enhances pretreatment of wastewater prior to being discharged.

The efficiency of the ATU is dependent on the aeration system supplying the proper amount of oxygen to the wastewater. Therefore, an ATU requires complex cleaning and, in some cases, frequent part replacements which are necessary to maintain optimal wastewater treatment. Although very effective at reducing biochemical oxygen demand (BOD), ATUs are more expensive to purchase and maintain than other treatment technologies (Ivery, 1995).

7.3. Media Filters

Media filters are a passive secondary and/or tertiary treatment system. They are fixed materials that provide easy movement of oxygen and water, as well as a surface area for microbes to establish themselves. As wastewater is sprayed or dripped over the surface of the media, water comes into contact with the microbes on the media. Through a combination of filtration and trapping, absorption, biological decomposition, and biochemical transformation, the media filters offer sufficient wastewater treatment (Jantrania and Gross, 2006). Consequently, the effluent will have a low BOD and total suspended solids (TSS) concentration (Jantrania and Gross, 2006).

Media filters can be utilized in one of two ways. First a single pass system will filter the wastewater once prior to being pumped to the dispersal system. The second option is a recirculation system which filters wastewater through multiple passes. A portion of water that passes through the media filter will be recirculated back into the septic tank to dilute the wastewater in the tank. This recirculation feature allows the wastewater treatment system to accept high hydraulic and organic loading (Jantrania and Gross, 2006). Therefore the efficiency of a media filter is dependent on the strength (ie. organic content) of the wastewater as well as the dispersal rate of the water over the medium.

Media filters may be placed in two major categories (Table 2). First, natural and mineral filters, including sand or gravel, expanded shale, cinders, limestone, activated carbon, peat or peat fiber, are materials that have high carbon contents (Eifert, 2007). In order to maintain the functionality of a media filter, the medium may need to be sprayed down with potable water or entirely replaced. The disposal of peat media filters, for instance, used in onsite wastewater systems may present an obstacle. The Commonwealth considers used peat as a biohazard due to the microbes that are living within the pores of the peat. This means that the peat cannot be directly disposed into a landfill. Therefore when peat is removed from the treatment system, the peat is air dried on the resident's lawn to allow for the active bacteria to die and then limed. The peat will then be bagged and sent to the landfill. This process may be considered time consuming and tedious. The second category is textile fabrics, including open cell foam cubes, hard plastic, crushed glass, tire chips, and process slag, that are uniform in size and shape, and have a high capacity for holding water.

Table 2: Types of media filters and there function (Jantrania and Gross, 2006)

Type:	Function:
Natural media	High carbon content
Sand and gravel filters	Single pass or recirculating filter options. High surface area for bacterial colonization. Adequate void space for airflow and aerobic processes. Large voids to prevent clogging. Single pass size 0.28 to 0.35mm; recirculating filter size 2 to 5 mm.
Peat or peat fiber filters	Single pass or recirculating filter options. High surface area with large void space. Low density. High coliform removal. May contribute to effluent being brownish, or tea, in color. Used peat is considered a biohazard.
Textile Fibers	Consistent size and shape. Works in recirculating mode. Large surface area and high water holding capacity. Two configurations: (1) small squares about 2"x 2" of ¼ to ⅜ in. thick fabric randomly packed in a container with capillary breaks between 4 to 6 in. layers and (2) hanging curtains of fabric about ½ in. thick.
Manufactured media filters	Uniform in shape and size. May be manufactured specifically to provide conductivity, porosity, storage capacity per unit volume, and lightness.
Open cell foam filters	Single pass or recirculating modes. Polyurethane foam material in 2 in. cubes placed in a prefabricated container. Large surface area for microbe establishment. Large voids and separate flow paths for wastewater and air. Dosing is controlled by a timer for uniform application.

The choice of filter is dependent on the quantity and quality of wastewater that is entering the system; however onsite alternative wastewater technology designers and installers may have product preferences that may factor into the decision.

7.4. Marshland Upwelling System

Marshland upwelling systems (MUS) are designed for the treatment of wastewater from coastal communities. Typically regional characteristics ideal for MUS include saturated and anaerobic sediments/soils (Evans and Rusch, 2007). This system utilizes the natural physical, biological, and chemical operations/processes that wetlands, and wetland sediments, provide in order to reduce organic matter, fecal pathogens, and nutrients in the wastewater (Evan and Rusch, 2007).

Although the specific design of the MUS may vary, the basic concept remains constant (Appendix A: Figure 4). As wastewater flows from the residence, or a cluster of residence, into a collection/distribution tank, the wastewater settles and is stored. The wastewater is then injected into the marshland through a well at a particular rate and frequency. There is a timer that activates and deactivates the pump to generate active and rest periods within the injection process. While the resting stage dissipates the pressure between the injection events, the active stages depend on advection forces to disperse the wastewater horizontally away from the point of injection (Fontenot, Boldor and Rusch, 2006). The injected wastewater becomes confined to a limited area due to a pressure differential created by the density difference between the saline groundwater and the wastewater (Watson and Rusch, 2001). This pressure also forces water toward the surface of the marsh, in the direction of the decreasing density (Watson and Rusch, 2001).

Researchers at Louisiana State University have assessed the MUS's ability to treat phosphorus, nitrogen, and fecal coliform loads within wastewater. The MUS was found to provide 99.6% and 99.7% treatment efficiencies for total phosphorus and *ortho*-phosphate (Evans and Rusch, 2007), while nitrogen removal efficiencies were found to be 98% and 98.6% for total kjeldahl nitrogen and total ammonia nitrogen (Fontenot, Boldor, and Rusch, 2006). Moreover researchers found that fecal coliform was reduced to levels below 14 MPN, which is the bacteria concentration standard for the National Shellfish Sanitation Program (Watson and Rusch, 2001). Although removal of fecal coliform, nitrogen, and phosphorus seems, it is uncertain how this treatment method will impact the future ecological integrity of the marshland.

7.5. Constructed Wetlands

Constructed wetlands are secondary and/or tertiary treatment systems. They use the natural physical, biological, and chemical processes that wetlands, and wetland sediments, provide through a combination of filtration, sedimentation, and bacterial decomposition.

There are two types of constructed wetlands (Appendix A: Figure 5). First, surface-flow designs allow wastewater to flow through a shallow basin planted with emergent and submerged macrophytes (Masi and Martinuzzi, 2007). Second, subsurface flow designs are filled with gravel or sand, or a similar substrate, where macrophytes are rooted (Masi and Martinuzzi, 2007). Macrophytes add oxygen to the system and increase the biological activity within the bed (Belmont et al., 2004). These systems may be planted with a variety of macrophytes, including reeds (*Pharagmites australis* or *communis*), bulrush (*Scirpus* sp.), cattail (*Typha* sp.), calla lily (*Zantedeschia aethiopica*), and canna lily (*Canna flaccida*). They all play an important role in the removal of various nutrients and metals through filtration, absorption, cation exchange, and root induced chemical changes in the rhizospheres (Liu et al., 2007). In addition to the macrophytes contributing to wastewater treatment, permanent or temporary anoxic conditions in wetland soils immobilize heavy metals (Liu et al., 2007). Masi and Martinuzzi (2007) found TSS, chemical oxygen demand (COD), BOD, total nitrogen and phosphorus were reduced by 84%, 94%, 95%, 60%, and 94% respectively.

Constructed wetlands are not only advantageous in the fact that they are efficient in treating wastewater, but a constructed wetland has the flexibility of being integrated into a centralized or decentralized system. Wetlands constructed for municipal or industrial wastewater treatment may be acres large. They provide an area for wildlife habitat, recreation, outdoor education, as well as an aesthetically pleasing view. However these systems are an ideal breeding ground for mosquitoes and may release an odor. Another aspect to consider is that constructed wetlands require maintenance and upkeep of the flora to efficiently treat the wastewater.

7.6. Membrane Bioreactor

Membrane bioreactors (MBR) are alternative technologies to traditional activate sludge processes for the secondary treatment of wastewater. They are fiber membranes with high surface areas that allow for maximum filtration of wastewater. Membrane bioreactors are either submerged (ie. immersed or integrated) or external (ie. recirculated or side-stream) membranes that combine the process of biological treatment with membrane technology. External membranes are situated outside of the bioreactor and the biomass is recirculated through a filtration loop (Yang, Cicek and Ilg, 2006). They are considered most suitable for industrial wastewater that has a high temperature, high organic load, extreme pH, high toxicity, and low filterability (Yang, Cicek and Ilg, 2006). However due to the high energy consumption of an external bioreactor, the submerged bioreactor is preferred. A submerged bioreactor (Appendix A: Figure 6) is introduced into an aeration tank to improve the separation of solids and water. The system is compact and is typically found in units called cassettes. They are used as ultra- and microfiltration membranes to retain both bacteria as well as viruses (Rosenberger et al., 2002).

8. Disinfection Methods

Prior to discharging effluent, in most cases, the wastewater is disinfected in order to meet state and federal water quality regulations. Typically this is considered tertiary treatment but depending on the system design may be referred to as quaternary treatment. These disinfection processes can be used for decentralized and centralized systems, however the concentration and/or amount of disinfectant is dependent on the quantity as well as the quality of the wastewater. Disinfection methods may be classified into three categories, including chemical, physical, and photochemical.

8.1. Chemical Disinfection

Chemical disinfection is based on the oxidization potential of a chemical. The chemical will oxidize and damage the cell wall of a microorganism and eventually cause lethal damage (Acher, et al., 1997).

Chlorination, the most common disinfection method in wastewater treatment, can be used in gas form (Cl_2) or a solid form known as sodium hypochlorite ($NaOCl$). For instance, onsite systems utilize calcium hypochlorite in a dry powder or in a tablet form, while centralized facilities use liquefied chlorine gas to disinfect. In both cases the chlorine will react with the ammoniacal-nitrogen and the organic matter in the sewage, as well as with the water (Forster, 2003). In order to disrupt the integrity of the cell membrane and damage the nucleic acids in the bacteria, the wastewater needs an exposure time of approximately 15-30 minutes. However the effectiveness of chlorine is dependent on the concentration of chlorine, and the temperature and pH of the water. Chlorine disinfection is advantageous since it is easy to handle, measure, dose, and control. Also it has a low capital cost and is considered cost effective. On the contrary, however, chlorine can react with organic compounds to form trihalomehtanes (THM) which may have detrimental effects to the receiving environment. Although research has found THM to be a carcinogen, other research has found that acute exposure to humans is not hazardous, and uncertainty prevails in regards to the exact affects on the environment (Fresse and Nozaic, 2004). Moreover, research has found that chlorinated water may consist of chloroform, bromodichloromethane, dibromochloromethane and bromoform (Symons et al., 1975).

Ozone, an alternative to chlorination in centralized systems, is a powerful disinfectant that kills microbes by targeting the enzymes and nucleic acids of bacterium, and damaging the nucleic acids of viruses. According to Freese and Nozaic (2004), ozone is more effective than chlorine in removing faecal streptococci organisms, coliphage organisms, and parasitic cysts and oocysts. Furthermore ozone has been found to remove more microorganisms at a lower dose than chlorine (Freese and Nozaic, 2004). Ozone is produced onsite as an electric current (5-25 kilovolts) is passed through dry air which results in a gas that consists of 1-2% V/V of ozone[a] (Forster, 2003). The effectiveness of ozone is a function of exposure time and concentration. On average, exposure time ranges from 5-10 minutes, however viruses and bacteria species vary in their sensitivities and resistance. Ozone is advantageous due to its ability to create a residual that is quickly dissipated. This reduces the effluents affects on the receiving environment. On the contrary, since the residual dissipates so quickly it is often necessary to supplement ozone disinfection with another disinfection method that has a longer lasting residual to ensure no re-growth occurs within the distribution system. Another drawback with using ozone is that it has a high capital cost when compared to other disinfection options.

Peracetic Acid is a manmade chemical which is a mixture of acetic acid (CH_3COOH) and

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[a] 1-2% V/V of ozone means the volume of ozone is 1-2% of the total volume of gas produced

hydrogen peroxide (H_2O_2). It is a relatively new wastewater disinfectant, but due to its bactericidal, virucidal, fungicidal and sporicidal effectiveness, peracetic acid has been considered a strong oxidant and therefore a strong disinfectant (Kitis, 2003). Compared to chlorine, peracetic acid is similar when disinfecting water with fecal and total coliforms as well as faecal streptococci (Freese and Nozaic, 2004). However peracetic acid was not found to be quite as efficient as chlorine when deactivating parasitic organisms (Freese and Nozaic, 2004). Optimal exposure time is 10 minutes. Although effective in disinfecting, peracetic acid is not a cost effective option due to its limited production. Moreover, the use of peracetic acid as a disinfectant may increase the amount of organic material in the effluent. This is due to the presence of acetic acid originally in the peracetic acid mixture, and is a result of the decomposition of peracetic acid (Kitis, 2004). Therefore an increase in organic content may result in the re-growth of microbes.

8.2. Physical Disinfection

Physical disinfection occurs when there is physical retention of microorganisms through filtration (ie. media filters, synthetic membranes or constructed wetlands). These methods have been previously discussed in the technology summary due to their abilities to reduce suspended solids, nutrients, and organic compounds in secondary wastewater treatment. Furthermore these methods provide effective disinfection and polishing before discharge or dispersal.

8.3. Photochemical Disinfection

Photochemical disinfection occurs when light (ie. Ultraviolet irradiation) induces chemical reactions within microbes.

Ultraviolet irradiation (UV) is a disinfectant that kills bacteria and viruses with a wavelength ranging from 200-280 nm over an exposure time of 6-10 seconds. This wavelength penetrates the cell membrane and ultimately damages the cell's DNA (Kolch, 1999). However if the dose of UV is not given at the lethal dose level, then the bacterial cells are able to repair the defective DNA through enzymatic processes (photoreactivation) (Acher et al., 1997). UV disinfection can be integrated into decentralized and centralized system designs through two manners: (a) flow-through open channel system or (b) a closed-pipe pressure system. The flow-through system consists of a mercury lamp in quartz tubes that are submerged at a controlled liquid depth in an open channel. The water flows parallel to the UV lamps and is exposed to the irradiation at a rate of 30-40 mWs/cm^2 (milliwatt seconds per square centimeter) (Acher et al., 1997). A closed-pipe pressure system, on the other hand, disinfects pressured water at a high intensity due to the rapid linear flow rate of water through the system. There are three main types of lamps: low-pressure/low-intensity, low-pressure/high intensity, and medium-pressure/high-intensity (Table 2). The total output of a lamp is dependent on the length of the lamp. For instance, the longer the lamp the higher the output. Moreover the effectiveness of UV disinfection is dependent on the depth, transmissivity, and turbidity of the water being irradiated as well as the bacterial concentrations (Freese and Nozaic, 2004). Similar to the ozone, ultraviolet radiation is advantageous since it does not create residuals or by-products as a result of its interaction with the microbes or the water. UV is also more effective than chlorine at killing *Legionella*, *Mycobacteria*, *Aeromonas*, *Cryptospordium* and *Giardia lamblia* which are harmful bacteria, parasites and pathogens to humans.

Table 3: Qualities of available UV lamps (Kolch, 1999)

Qualities of Currently Available UV Lamps

Parameter	Low/Low	Low/High	Med./High
Power consumption[1]	15W-70W	120W-260W	4 kW
Efficiency[2]	40 percent	35 percent to 40 percent and more	10 percent to 15 percent
Lamp output[3]	0.1-0.2 W/cm 245 nm	0.5-1.0 W/cm 254 nm	3 W/cm UVC total
Temperature[4]	30°C	100°C	600°C
Lamps needed for 18 mgd[5]	~100	~30	~5
Total power consumption	7.5 kW	7.8 kW	20 kW

1. The power consumption varies according to different lamp sizes. Thus, the given data are for the most common low/low lamps used in drinking water applications.
2. The efficiency refers to the percentage of electrical energy transferred into bactericidally effective wavelengths. The data given are typical. Individually, results might vary because of different lamp operations (ballasts), temperatures and other site-specific effects.
3. Low- and medium-pressure lamps have very different emission spectra. Whereas low-pressure lamps are more or less monochromatic in the UV-C region, medium-pressure lamps emit a polychromatic continuum in that range. Therefore, the 254-nm output would under-estimate the efficiency of medium-pressure lamps, whereas the figure provided in the table overestimates it a bit. This is because the entire UV-C range cannot be weighted equally.
4. The data are surface-operation temperatures. The difference between this temperature and the operational site-specific (water) temperature could affect the lamp operation (output). The higher the difference between the surface and water temperatures, the lower the operational effects. Thus, medium-pressure lamps operate independently of water temperatures. However, high temperatures can result in a tendency for fouling or for the quartz sleeves to become covered with matter such as humic acids, ferric iron and manganese. Additionally, high-temperature lamps depend on continuous cooling. From that standpoint, the low/high lamp can be looked upon as a sort of compromise that covers the advantages of the low/lows and the med./highs.
5. The data shown here are based on the assumption of 3 W/m^3/hour.

9. Effluent dispersal

As a result of wastewater treatment there are two end products: solid waste and effluent. Due to the scope of this paper, dispersal and discharge of the effluent will only be discussed in the following section.

9.1. Subsurface Dispersal

Subsurface soil treatment, typically used for only decentralized systems, utilizes the soil to not only dispose of the effluent, but to purify the effluent. The performance of a subsurface dispersal system is dependent on the effluent characteristics, methods of application to the soil, and site characteristics (Jantrania and Gross, 2006).

Soil has a variety of characteristics, including texture, structure, and percolation rates that make it very effective in removing nutrients, solids, pathogens, chemicals, and organic matter. Soils consisting of oxygen create an ideal environment for aerobic bacteria to survive and thus assist in the breakdown of residual organic matter in the effluent. Oxygen in the soil also indicates unsaturated conditions in the soil. This allows for the wastewater effluent to have adequate contact time with the soil particles and bacteria for sufficient treatment. The depth of the soil, however, plays a role in the presence of oxygen. For instance, the amount of oxygen available at soil depths greater than 48 inches is greatly reduced (Anderson and Gustafson, 2004), which consequently reduces the efficiency of soil treatment. Prior to installation of a system, soil texture is assessed to determine the amount of sand, silt, and clay particles within the soil as well as the size of the particles. Though the soil texture is absolutely pertinent when designing and sizing a system, the flow and loading rate of the system also needs to be considered (Table 4).

Table 4: Soil Sizing Factors Based on Percolation Rates (Anderson and Gustafson, 2004)

Percolation rate (minutes per inch)	Soil texture	Sizing factor (sqft/gal/day)	Loading Rate (gal/day/sqft)
Faster than 0.1[a]	coarse sand	0.83	1.20
0.1 to 5[b]	medium sand, loamy sand	0.83	1.20
0.1 to 5	fine sand	1.67	0.60
6 to 15	sandy loam	1.27	0.79
16 to 30	loam	1.67	0.60
31 to 45	silt, silt loam	2.0	0.50
46 to 60	sandy clay loam, silty clay loam, clay loam	2.2	0.45
61 to 120[c]	silty clay, sandy clay, clay	4.2	0.23
Slower than 120[d]		--	---

[a] Systems installed in or on these soils must be either mound systems or trench systems with at least 1 foot of clean sand between the distribution medium and the coarse soil of the trench bottom and side walls.
[b] Systems in or on these soils must use pressure distribution or must be divided into at least four parts, none of which is more than 25% of the total system area, and which are in series.
[c] Mounds should be used for system on these soils.
[d] Systems installed in or on these soils should be monitored.

Some soil factors that may limit the installation of a dispersal system include bedrock, sandy soils as well as saturated soils. Bedrock is relatively impermeable to water percolation, but bedrock may consist of cracks and channels that could potentially direct water flow toward groundwater aquifers (Anderson and Gustafson, 2004). Saturated soils have reduced oxygen levels, which decreases the amount of aerobic bacteria present in the soil that are significant for wastewater treatment. Finally, sandy soils limit efficient soil disposal and treatment due to the high percolation rate. Such a rate reduces the amount of contact time the effluent has with the soil and aerobic microbes for digestion. In a 2002 publication by the USEPA recommendations were made for dispersal systems when considering limiting factors and soil depth (Appendix B: Figure 1).

There are a variety of soil dispersal systems options that can be utilized in onsite systems, but may also be considered in cluster wastewater systems. Historically soil treatment systems such as cesspools, seepage pits, and leaching pits have been used as disposal systems. Although these systems may still be found in rural areas, they are not highly efficient in treating wastewater. Fortunately there have been advancements to subsurface treatment systems and may be grouped in the following categories:

- Trenches or beds filled with gravel or other media (Appendix B: Figure 7)
- Gravelless trenches or beds with chamber systems (Appendix B: Figure 8)
- At-grade or above-grade (Appendix B: Figure 9)
- Drip dispersal (Appendix B: Figure 10)
- Spray dispersal (Appendix B: Figure 11)

Within trenches or dispersal bed systems, piping may be covered with gravel, or other media, or no gravel at all. The idea is that the gravel, or the media surrounding the piping, will assist in the final disinfection stage of wastewater treatment.

At-grade systems are built on the original grade or slope of the land (Anderson and Gustafson, 2004). The system consists of an additional layer of sand, or filtering media, on the soil surface and is than capped with soil (Middlebrooks, Reed, and Crites, 2005). Above grade systems, also referred to as mound systems, are built without using clean sand and are positioned above the natural grade of the land (Anderson and Gustafson, 2004). In both systems, however, the size and shape of the mound will affect the absorption of effluent. Research has shown that relatively long and narrow mounds absorb effluent most effectively, particularly in areas where heavy soils are present (Anderson and Gustafson, 2004).

Drip dispersal, otherwise referred to as drip irrigation, has the primary goal of applying small amounts of effluent to a large area (Anderson and Gustafson, 2004). The effluent from wastewater treatment technologies are a source of nutrients and moisture for the growth of vegetation. Consequently, drip dispersal systems can be designed to irrigate an entire yard, which ultimately decreases the use of potable water to irrigate lawns and/or gardens.

Spray irrigation methods may be integrated into decentralized or centralized system designs. Application of treated effluent is directly sprayed to the soil surface. Similar to drip dispersal, spray irrigation utilizes the nutrients in the effluent to irrigate the land. According to a study from the Pennsylvania Department of Environmental Protection (PDEP) the increasing use of spray irrigation in residential communities increased the base flow within the watershed as well as the recharge rate of groundwater, however it was also found to negatively affect the water quality of shallow aquifers (Schreffler, et.al., 2005).

9*.2. Surface discharge*

As the name suggests, surface discharge is when treated effluent is discharged directly onto land or into water (ie. rivers, streams, wetlands, lakes, oceans). This is typically referred to as a point source discharge since there is a single, end of the pipe discharge that is monitored. The Commonwealth of Virginia requires all point source discharges into water obtain a VPDES permit, while a VPA permit is issued for direct land application of effluent.

10. Cost Assessment

The cost of alternative wastewater treatment technologies will vary on a case to case basis. Factors contributing the cost of the system will include the quantity of water, and the quality of water being treated as well as the preference of the installers or engineers designing the system.

A collection of cost estimates of decentralized systems have been assembled in Table 5 from literature, government documents, and from consultants. The total costs include the capital costs incurred in planning, designing, and constructing the system and the long term costs associated with maintaining a system with a design flow of 440 gallons per day for a four bedroom house over a life span of 20-30 years (in most cases) (Hoover, 1997).

Table 5: Examples of a total cost summary worksheet to compare alternatives[a].

System	Total materials & installation	Present value of total O&M cost	Total cost over life of system	Amortized monthly materials & installation costs	Avg monthly present value of O&M costs	Avg monthly cost over life of system
Septic tank & gravity distribution	$2,504	$6,845	$9,349	$20	$19	$39
Septic tank & gravity distribution with chambers	$3,336	$7,032	$10,368	$27	$20	$46
Septic tank & gravity distribution with styrene foam	$2,846	$6,920	$9,767	$23	$19	$42
Septic tank & gravity distribution with large diameter pipes	$3,816	$7,156	$10,971	$31	$20	$51
Septic tank & gravity distribution with pressure manifold	$4,774	$7,707	$12,482	$38	$21	$60
Septic tank & gravity distribution with pressure manifold and chambers	$5,593	$7,889	$13,482	$45	$22	$67
Septic tank & gravity distribution with pressure manifold and styrene foam	$,5,103	$7,777	$12,881	$41	$22	$63
Septic tank & gravity distribution with pressure manifold large diameter pipes	$6,073	$8,013	$14,085 $15,356	$49	$22	$71
Septic tank & gravity distribution with sand filter pretreatment	$7,296	$12,069	$19,364	$59	$34	$92
Septic tank & gravity distribution with peat filter pretreatment	$11,808	$12,604	$24,412	$95	$35	$150
Septic tank & gravity distribution with recirculating sand filter pretreatment	$6,226	$12,059	$18,285	$50	$33	$84
Septic tank & LPP distribution	$4,523	$12,319	$16,843	$36	$34	$71
Septic tank & LPP distribution with sand filter pretreatment	$10,223	$13,338	$23,561	$82	$37	$119
Septic tank & LPP distribution with recirculating sand filter pretreatment	$8,232	$13,007	$21,239	$66	$36	$102
Septic tank & drip distribution	$11,163	$13,082	$24,245	$90	$36	$126
Septic tank & drip distribution with sand filter pretreatment	$15,994	$14,101	$30,095	$129	$39	$168
Septic tank & drip distribution with recirculating sand filter pretreatment	$14,872	$14,094	$28,966	$120	$39	$159

Septic tank & drip distribution with sand filter pretreatment & chlorine disinfection	$16,408	$21,244	$37,652	$132	$59	$191
Septic tank & drip distrib. with recirc. sand filter pretreatment & chlorine disinfection	$15,285	$21,237	$36,522	$123	$59	$182
Septic tank & drip distribution with sand filter pretreatment & UV disinfection	$17,867	$21,655	$39,522	$144	$60	$204
Septic tank & drip distribution with recirc. sand filter pretreatment & UV disinfection	$16,744	$21,757	$38,501	$135	$60	$195
Septic tank & spray irrigation with sand filter pretreatment and chlorine disinfection	$11,890	$20,670	$32,580	$96	$57	$153
Septic tank & spray irrigation with recirc. sand filter pretreatment and chlorination	$10,768	$20,663	$31,431	$87	$57	$144
Septic tank & spray irrigation with sand filter pretreatment and UV	$13,349	$21,190	$34,539	$107	$59	$166
Septic tank & spray irrigation with recirculating sand filter pretreatment and UV	$12,227	$21,183	$33,410	$98	$59	$157
Septic tank and gravity distribution with wetland cell	$5,574	$23,231	$28,805	$45	$65	$109
Aerobic treatment unit and gravity distribution	$8,037	$36,406	$44,443	$65	$101	$166
Denitrification system blackwater & graywater separation and gravity distribution	$9,963	$13,508	$23,471	$80	$38	$118
Denitrification system blackwater & graywater separation and LPP distribution	$12,565	$15,070	$27,635	$101	$42	$143
Septic tank & gravity distribution with 18 inch fill mound	$4,507	$6,850	$11,357	$36	$19	$55
Septic tank & gravity distribution with 18 inch fill mound and chambers	$5,326	$7,032	$12,357	$43	$20	$62
Septic tank & LPP distribution in at-grade system	$4,590	$12,345	$16,935	$37	$34	$71
Septic tank & pressure-dosed sand mound system	$4,863	$12,407	$17,269	$39	$34	$74

[a] Costs displayed are not typical for all states. Costs in other states are significantly higher.
Source: Hoover, 1997.

While MBR technology is consistently improving, the cost has steadily decreased over the last 10 years. MBRs have become a favorable option due to the increasing costs of conventional technologies that are affected by labor costs and inflationary pressure (Chapman, Leslie, and Law, 2004). Fouling is considered a major limitation of this technology, but research is exploring new techniques to reduce fouling effects. Currently chemical cleaning and physical removal of colloidal particles and cell debris from the membrane, through back washing, is utilized to maintain membrane functionality. However such processes add to the operation and maintenance costs of this technology option. Ultimately the depreciation for the mechanical equipment and the replacement of the membranes strongly influence the annual cost of the installation of the MBR (STOWA, 2006).

The cost of constructing a wetland will depend on the particular project at hand, but the design flow as well as the types of macrophytes used in the wetland will vary the price. According to a study by the USAEC and Tennessee Valley Authority the estimated amortizing capital cost of a .12 acre wetland in Milan, TN over a 10 year period results in a cost of $1.36/Kgal; over a 30 years period, the cost is $0.45/Kgal (Federal Remediation Technologies, 2008).

11. Conducting an alternatives analysis

This-sub-section profiles the expected economic impact of conducting any "Alternatives Analysis" so as to better select an ecologically sound and economically cost-effective management option to manage wastewater and not affect shellfish aquaculture. Each locality proposing a new or expanded sanitary wastewater discharge may have varying requirements and/or needs in terms of their adoption of the analysis. Summarized below is a thematic description of the analysis process followed by a best guess estimate of the potential costs of undertaking such an analysis:

The analysis is comprised of the following two phases.

Phase 1: Technical feasibility

This phase would involve an assessment of the land availability for alternative treatment of surface water discharge and also the related soil composition and type. Such an assessment would cost approximately $30,000 and could vary based on the nature and size of expansion. This best-guess estimate is the cost that all permit applicants subject to the regulation would have to incur as Phase 1 s required of all applicants.

Phase 2: Environmental analysis and socio-economic impact analysis

This phase would typically involve an assessment of the environmental and socio-economic effects of adopting the select alternative technology. Environmental analysis would include a review of groundwater impacts, swimming or recreational impacts and shellfish condemnations.

> Socio-economic impact analysis of any technically feasible alternative would include an analysis of the affordability of the land, technology, positive and negative tax revenue impacts to the locality, eco-tourism, recreation and aesthetics.

Such an analysis that includes an accounting assessment of the technology options and mitigation measures and socio-economic welfare assessment for a typical proposed expansion of a locality's wastewater discharge could cost the applicant approximately $35,000 to $55,000.

Thus, the total net cost burden to an applicant as a result of conducting any analysis would be in the range of $30,000 for Phase 1 and total net costs of conducting Phase 1 and 2 analyses would be $65,000 - $100,000. Conducting such an analysis would provide applicants, community/locality residents, coastal community planners and regulators with additional information to better protect high quality waters that are suitable for shellfish growth. Furthermore, it would assist in improving regulatory consistency and clarity in terms of areas of high quality waters for current and/or future shellfish resources and also provide necessary guidance on VPDES permit application process for proposed new or expanding facilities that may have surface discharge of sanitary wastewater. Lastly, it would assist in assessing the socio-economic impacts of proposed project in terms of its selecting alternative treatment technology or undertaking surface water discharge.

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Appendix A: Technology Summary

Figure 1: Conventional systems consisting of only a septic tank and drainage field (http://earthsci.org/education/teacher/basicgeol/sewage/septic-system.gif, 2008)

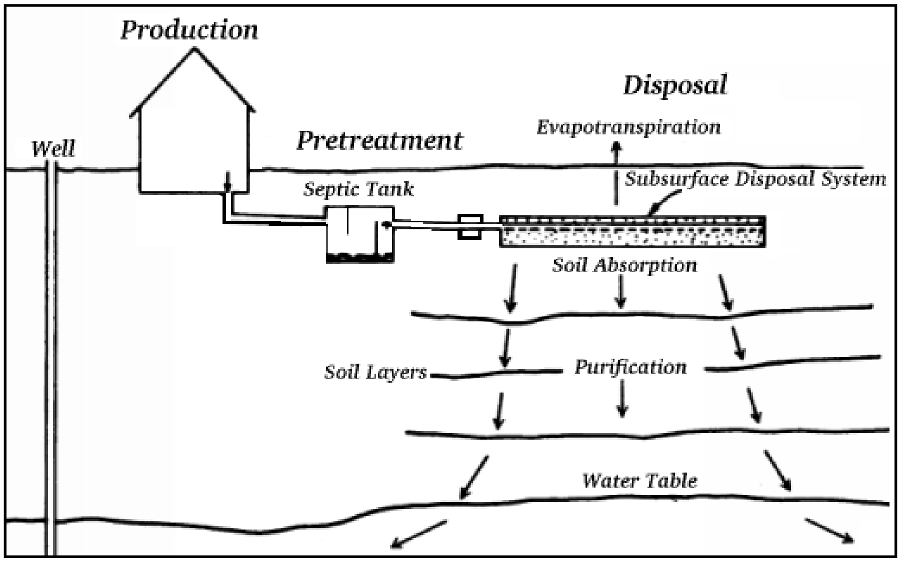

Figure 2: Conventional septic tank. http://extension.missouri.edu/explore/images/eqm104fart02.jpg

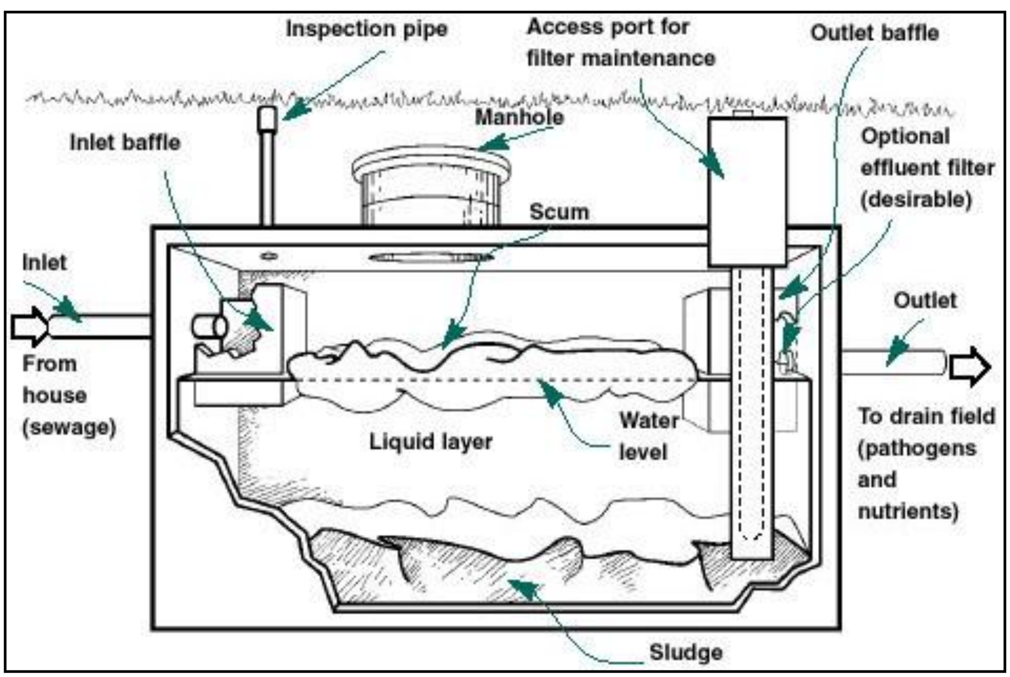

Figure 3: A general design of an aerobic treatment unit (ATU). http://extension.missouri.edu/explore/images/wq0403art02.jpg

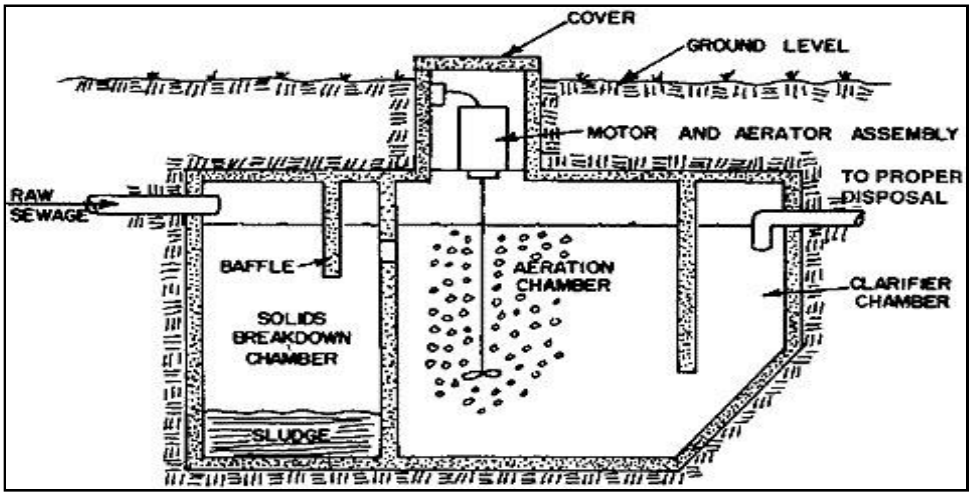

Figure 4: Marshland Upwelling System (Evan and Rusch, 2007)

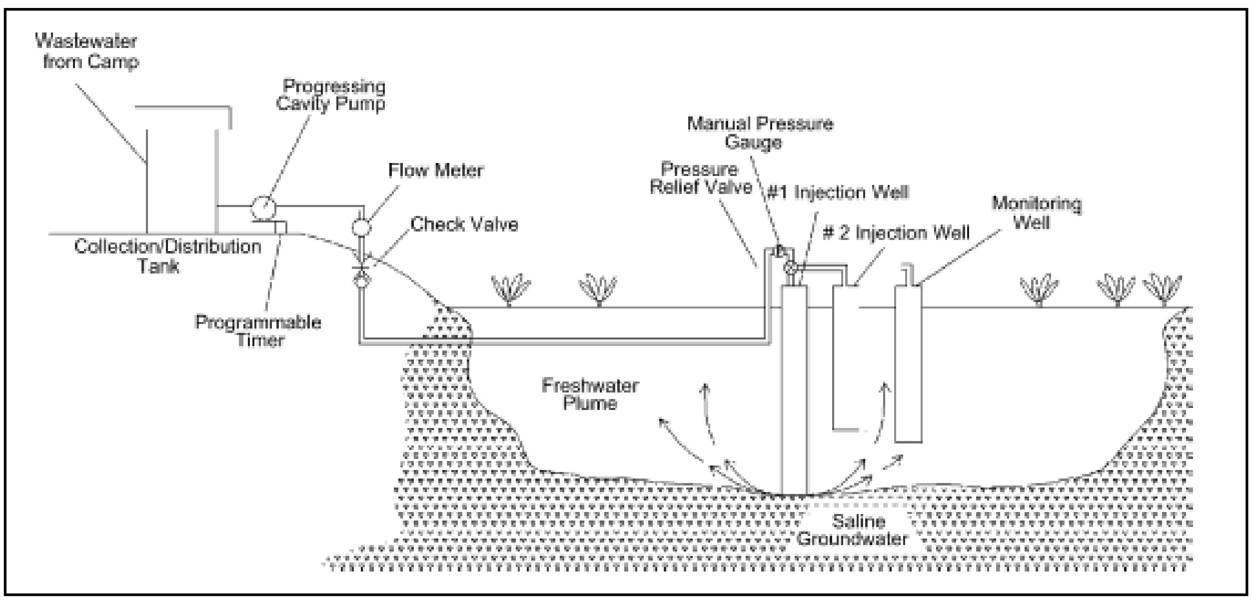

Figure 5: Constructed Wetland System (Masi and Martinuzzi, 2007) [Note: *Phagmites* would not be considered in the construction of wetland in the Commonwealth of Virginia due to its invasive qualities]

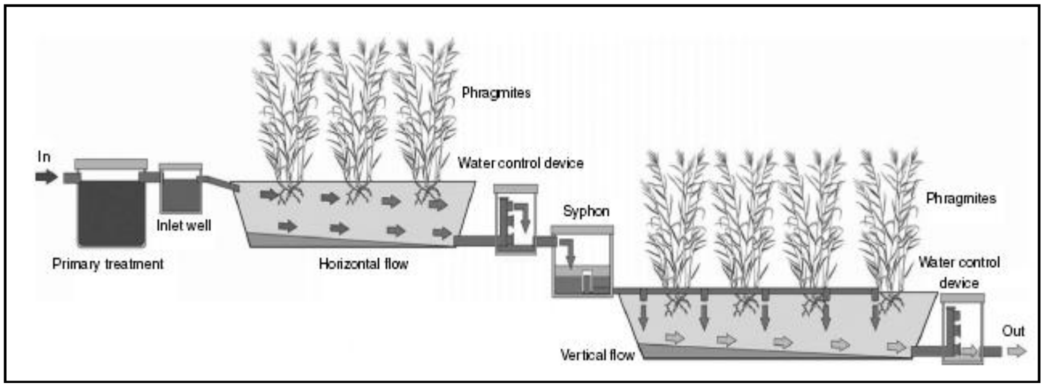

Figure 6: Configuration of a bioreactor (Rosenberger et. al, 2002)

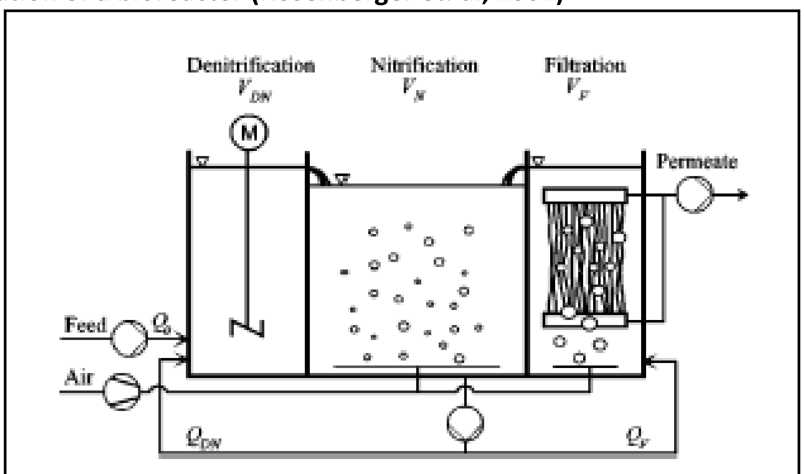

Fig. 1. Configuration of the bioreactor.

Appendix B: Subsurface dispersal

Figure 1: Placement of Infiltration system, given limiting factors and soil depth (EPA, 2008)

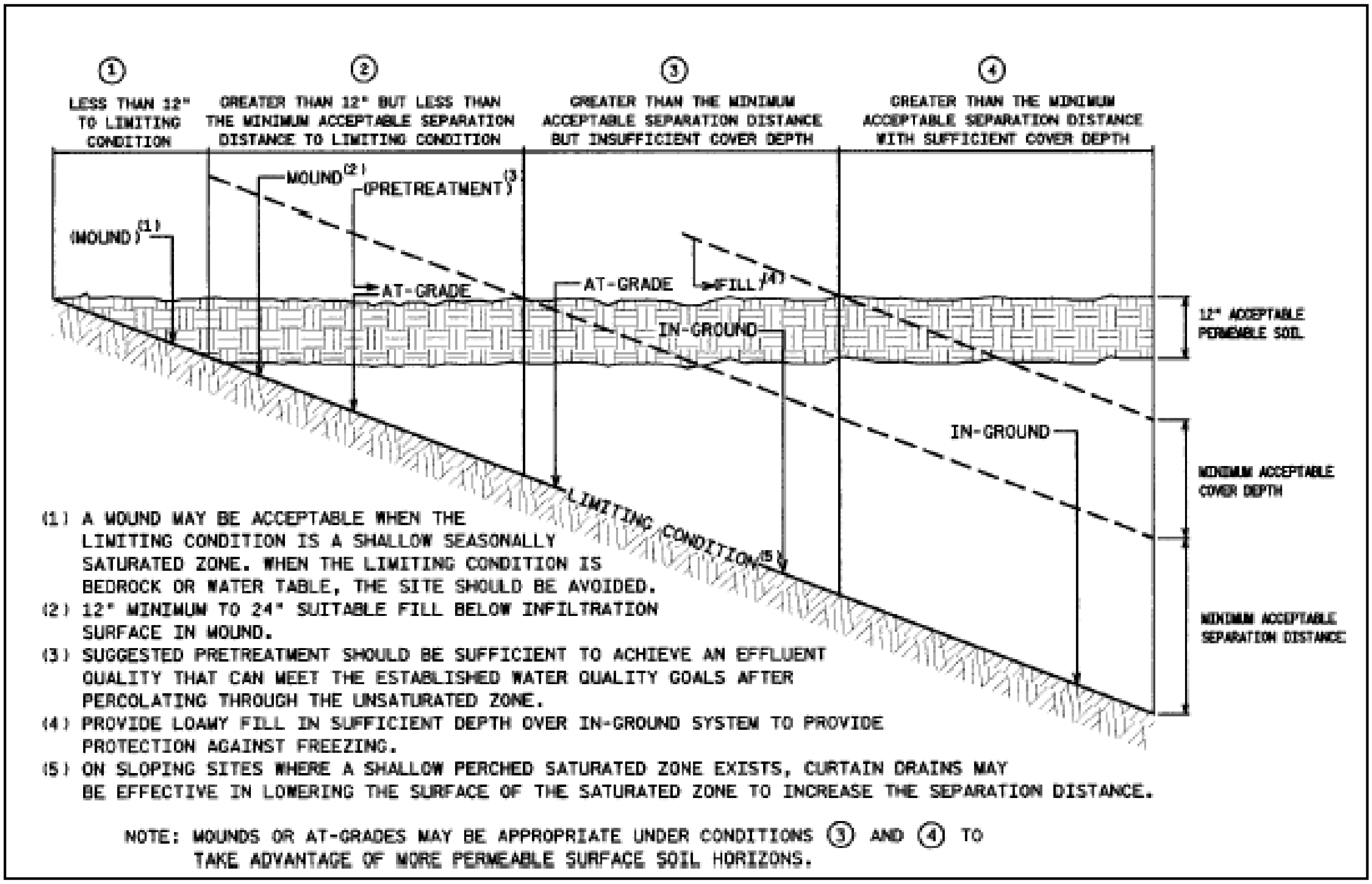

Figure 2: Gravel filled trench. Gravel is placed around the pipe to maintain the proper contour (Hammond and Tyson, 1991).

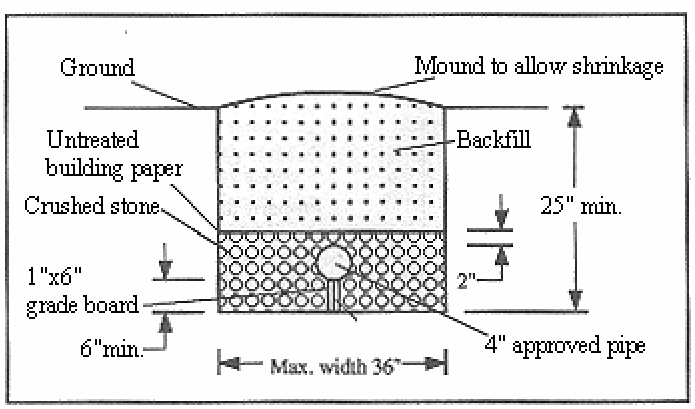

Figure 4. Cross-section of a typical drainfield line

Figure 3: Cross section of a gravelless trench drainfield (Selecky, 2007)

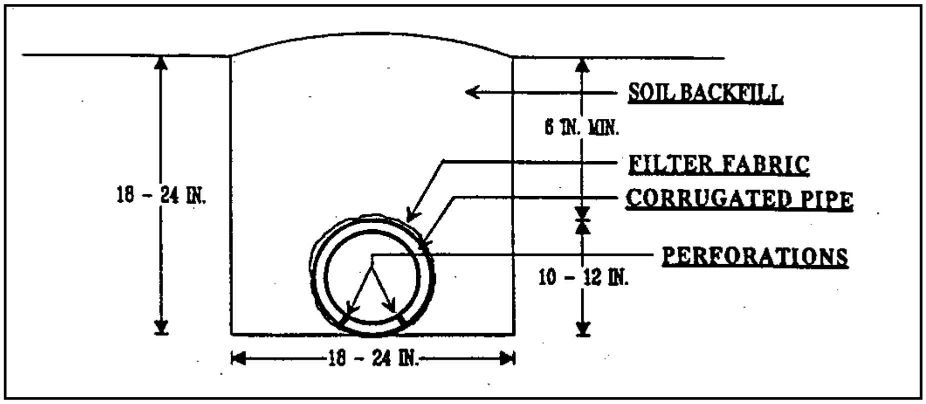

Figure 4: Above grade mound dispersal system (EPA, 2008)

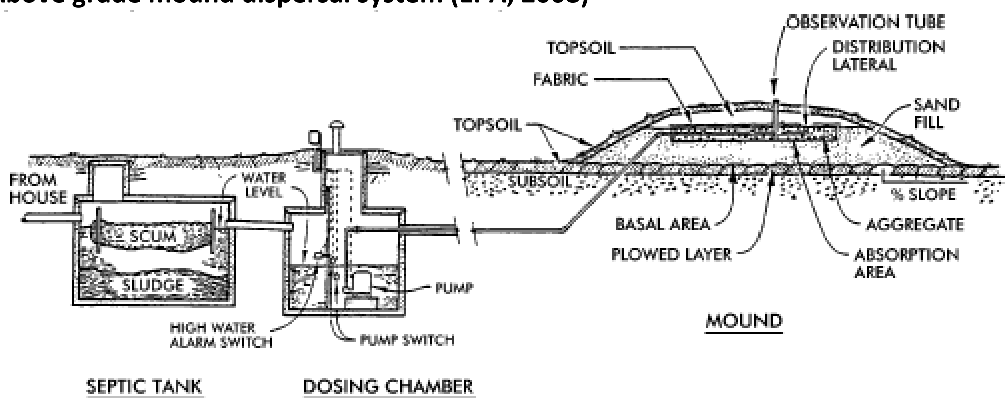

Figure 5: Drip dispersal and irrigation (ie. Zone 1 and 2) (T.G. Rankin, 2008)